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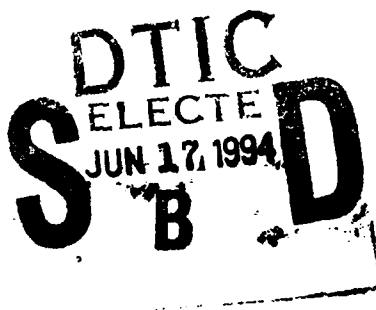
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## SPACE SYSTEMS ENVIRONMENTAL INTERACTION STUDIES

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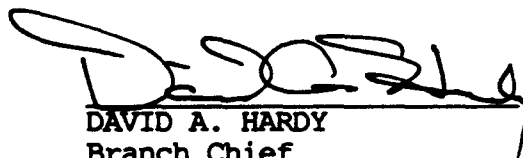
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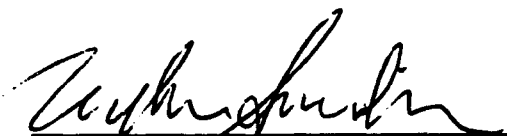
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## 1. INTRODUCTION

This is the second interim scientific report for Contract #F19628-91-C-0112, whose objective is to investigate spacecraft-environment interaction and space-plasma dynamics issues, especially as they relate to differential charging, discharge mechanisms, coupling between plasmas and space power systems, wake formation mechanisms, EM wave-particle interactions, and long-term radiation effects on operating systems in space.

The work is to be accomplished in three distinct *in-situ* investigatory programs (identified as Task #s 1, 2 and 3) and the completion of a data analysis and presentation period. Significant efforts were expended on Task #1 and Task #3 this past year, with somewhat less being carried out on Task #2. This report details the efforts expended on these three tasks over the last twelve months. The material is presented in serial order, with issues relating to Task #1 discussed first in Section 2. Performance information on the critical heart of the payload—the experiment Controller—is presented in Sections 3, 4 and 5. The year's activities on Task #2 and Task #3 are covered in Section #6 and Section #7, respectively.

## 2. TASK #1 - PASP Plus EFFORTS

The objectives of Task #1, which will be accomplished when the Photovoltaic Array for Space Power Plus Diagnostics (PASP Plus) experiment is launched, are: (1) to measure the environmental interaction of advanced solar arrays in relation to environmental conditions, when the arrays are subjected to bias voltages up to  $\pm 500$  V, (2) to determine the long-term radiation degradation effects on various array materials, and (3) to flight-qualify various array designs. The launch vehicle will be the Advanced Photovoltaic and Electronics Experiment (APEX) satellite, which will be placed into an elliptical orbit with a nominal perigee of 350 km ( $\approx 195$  nm) and nominal apogee of 1850 km ( $\approx 1054$  nm) by a Pegasus air-launched vehicle, provided by Orbital Sciences Corp.

### 2.1 Summary of Activities

Amptek, Inc. acted largely in a support role to PL/GPSG on the PASP Plus Program this past year. The PASP Plus flight equipment was integrated onto the APEX satellite at OSC's integration facility in Chantilly, VA. Since Amptek, Inc. was tasked with fabricating most of the connecting harnesses between the various instruments which make up the PASP Plus payload, company personnel were on hand to assist in this effort. About a week prior to the event, a much delayed APEX bench-system Pre-Compatibility Test was carried out. This was a test of non-flight versions of the various spacecraft subsystems and payloads, in otherwise flight configuration, carried out primarily to check the functionality of the system software.

In order to properly support this exercise, test harnesses, which allowed the simultaneous monitoring of both the PASP Plus Controller's GSE port and the spacecraft's downlinked telemetry, were made and provided by Amptek, Inc. The test clearly established that the Controller could be properly addressed by the spacecraft, despite problems in doing so for any length of time, due to software bugs and other interruptions which cropped up repeatedly during the course of the exercise.



A full Comprehensive Performance Test (CPT) was carried out after integrating the PASP Plus equipment to the spacecraft to ensure that it was all in proper working order. PASP Plus personnel supported this six-hour exercise, which was concluded successfully. Later, additional performance enhancement measures were undertaken on some of the integrated payload equipment. Amptek supported this activity, in both equipment procurement and subsequent instrument functionality checkout, with the PASP Plus GSE.

PASP Plus fell into a 'low-level' effort status at Amptek, Inc. by the middle of this review period, reflecting in large measure, the schedule delays that were occurring on the APEX program. The satellite provider and payload integrator experienced continual difficulty in meeting scheduled milestones, due to both hardware and software problems. The principal effort expended during this period was in PASP Plus support during weekly teleconferenced program status reviews. A technical support activity that did take place was the APEX-integrated power-ON checkout. Amptek personnel supported this test, which verified at the pin-to-pin level that the APEX power and signal harnesses to the PASP-Plus Controller were of the proper functionality and voltage levels. After establishing that this was the case, a follow-on Limited Performance Test, which PL/GPSG conducted on the PASP Plus payload, was also supported by Amptek.

Some effort also went into preparing for the APEX Comprehensive Performance Test (CPT) during the quarter. GSE software resident on the APEX telemetry decommutating module—referred to as the Spiderbox—was upgraded for this test. Previous differences between the basic PASP Plus housekeeping parameters displayed on the Spiderbox monitor and those displayed on the diagnostic GSE monitor were removed. The Spiderbox was also made to be fully capable in the APEX telemetry contingency mode; i.e., the unit was upgraded to support the 16 Kbit/sec APEX downlink data rate as well as the normal 128 Kbit/sec rate. Both telemetry modes were tested during the exercise.

An APEX CPT dry-run was supported by Amptek personnel. For this exercise, an optically isolated GSE harness was built and installed at the test facility. In a manner similar to what was done during the APEX bench system Pre-Compatibility Test, the telemetry downlink seen at the spiderbox and that displayed on the diagnostic GSE console from a direct link to the Controller's GSE port could be both viewed and recorded simultaneously. The difference here is that with an opto-isolated diagnostic GSE link, this connection could still be maintained even during those portions of the CPT when the spacecraft is not electrically grounded. Thus, an independent means of verifying the data contained within the telemetry downlink was made possible for the entire duration of the test. The added measure of a bit-by-bit comparison of the two data streams must still be carried out, but this is a relatively trivial undertaking. Amptek Inc. personnel installed and verified the proper functionality of the complete PASP Plus GSE arrangement prior to the start of the test.

The APEX CPT dry-run was to be an immediate precursor to the CPT. However, due the various problems which emerged during the exercise, the formal CPT was postponed, and it did not commence as initially scheduled. Then, due to repeated setbacks, it eventually took some two months to complete. Amptek, Inc. personnel were not on-site during the course of the test, but support was rendered to the PL/GPSG test team by means of telephone and fax communication. There were several occasions on which this was done, but in none of these instances was the proper functionality of the equipment in question.

Somewhat in tandem with CPT activities, work on completing the spiderbox software resumed. The current software task is to manage on-orbit GSE operations at the mission control center (CSTC in Sunnyvale, CA) and display data from not only the real-time portion of the downlinked telemetry (a feature the diagnostic GSE has been capable of doing for sometime now), but also to display instrument-specific data for each payload unit from the stored historical data dumps that are made during each ground-contact period. In order to accomplish this task, instrument specific display screens must be developed. Also, algorithms to extract and order the data as well as rudimentary data base organizational code, have be written. This effort is on-going.

The GSE setup at CSTC will actually be in the form of a Local Area Network (LAN) of five PCs. The fastest machine (having a 486 66MHz microprocessor) will be the spiderbox, and it will also be a server to the other units. Real-time and historical data will be stripped out of the APEX downlink and sent to a PC dedicated to the Dosimeter displays. The other three PCs will have independent means of accessing and displaying data from the other instruments in the payload, which is similarly stripped out of the APEX downlink and stored on the spiderbox hard disk. Protective features will be incorporated into the spiderbox software to ensure that whatever activity is on-going when the downlink starts up is interrupted and that the in-coming telemetry is properly received and stored, whenever it becomes available. Amptek, Inc. is tasked with setting-up the LAN on PL/GPSG provided PCs and providing whatever software is necessary to do the job.

In other activities, the preparation of what is to be the final item in PASP Plus documentation commenced. The document, entitled *Handbook of Controller Functions & Operations*, is to be a compilation of information that relates to the operation and functionality of the PASP Plus Controller. The intent is make available all the necessary material that could serve as the final reference for on-orbit operations, especially during investigations into non-nominal events. Accordingly, design, test and performance related material will be incorporated that might not have made it into other documents on Controller operation. A list of the other two defining documents for PASP Plus, which were previously released by Amptek, Inc., are indicated below in Table 1.

Table 1: Released PASP Plus Documentation

| TITLE   | RELEASE DATE        | DOCUMENT NUMBER |
|---|---------------------|-----------------|
| PASP-Plus COMMAND FORMATS<br>&<br>TELEMETRY ALLOCATIONS<br>- Instruments, Housekeeping and Array Details<br>for all 30 Minor Frames | Jan-26-94<br>REV. 4 | PASP-FMT.DOC    |
| Interface Control Document<br>for the<br>Photovoltaic Array Space Power Plus<br>Diagnostics (PASP Plus) Program                     | Aug-17-93<br>REV. 1 | PASP-ICD.DOC    |

### 3. CONTROLLER SATELLITE INTERFACES AND PAYLOAD COMMANDING

#### 3.1 Power

The PASP Plus Controller consumes 7.6 W nominally (9.0 W maximum) at +28 V, without any other payload unit powered ON. The power draw for individual instruments is shown in Table 1. The numbers do not reflect the turn-on inrush current to the units. While this can exceed the MAX current indicated by several orders of magnitude, it occurs for less than 300 ms, worse case.

Table 2: PASP Plus Instrument Power Requirements

| INSTR                         | Vdc                             | COMPONENT                                 | TOTALS                                      |
|-------------------------------|---------------------------------|---|---|
| Controller powered ON         | +28 ± 4                         | Without other units                       | 7.6W NOM<br><u>9.0W MAX.</u>                |
| Sun Sensor<br>Sensor Head     | +28 <sup>+5</sup> <sub>-4</sub> | Electronics Unit                          | 0.6W NOM.<br>negligible<br><u>0.7W MAX.</u> |
| Langmuir Probe<br>Sensor Head | +28 ± 4                         | Electronics Unit                          | <u>3.5W MAX.</u>                            |
| ESA                           | +28 ± 6                         | 0.5 W NOM.                                | <u>0.65W MAX.</u>                           |
| TPM                           | +28 ± 12                        | Electronics Unit                          | 12.1W NOM.<br>13.5W MAX.                    |
|                               | +10.5 ± 0.21                    | E <sup>+</sup> Field Sensors              | 50mW MAX.<br><u>13.6W MAX.</u>              |
| Emitter                       | +28 ± 4                         | Electronics Unit and<br>Filament Assembly | 27.0W NOM.<br><u>35W MAX.</u>               |
| QCM                           | +15 ± 0.15<br>+28 ± 4           | Oscillators<br>Heater                     | 30mW NOM.<br>1.25W NOM.<br><u>1.5W MAX.</u> |

The PASP Plus Sun Sensor and Calorimeters become fully functional when the Controller is powered ON. The other instruments in the payload will remain OFF until commanded otherwise by ground command. Housekeeping status, Calorimeter status and Sun-Sensor outputs will be sampled and telemetered autonomously.

### 3.2 Over-Current Protection

There are two modes of over-current protection provided to PASP Plus. A *startup* mode and an *over-current* mode. Immediately after turning power ON to the Controller, over-current monitoring is as defined for the start-up mode. Current draw is first sampled (the average of four readings taken 32  $\mu$ s apart) between 20 to 30 ms after power ON, and then every 250 ms thereafter, up to 5 seconds, for the startup mode duration. If any sample exceeds the startup shutdown current limit of 3.0 amps within this period, power is turned OFF between 10 to 260 ms of the event. The minimum relay switching time is 10 ms.

Beyond the 5-second duration of the startup mode, over-current monitoring is as defined for the runtime mode. Current draw is sampled approximately every 250 ms, and power is turned OFF between 10 to 260 ms after the second of two consecutive samples which exceed the runtime shutdown current limit of 2.5 amps. In this mode, therefore, the delay from the onset of an over-current condition to the point where power is turned OFF will be between 260 ms and 510 ms.

### 3.3 Serial Interface

Data to and from the Controller is transferred asynchronously, according to EIA RS-422 specifications, at a data rate of 19.2 Kbits per sec, 1 stop bit, 1 start bit, 8 data bits and no parity. No handshake lines are used.

APEX is required to send a 4-byte serial message to PASP Plus every second, consisting of a 2 byte PASP Plus Command and a 2-byte APEX Data Request Command (5F00h). If there is no pending PASP Plus command, APEX shall by default issue a *NO-OP* (0000h) command.

The LSB (bit 0) of the PASP Plus Command byte is the parity bit. It is set such that the total number of 1's in the entire 4-byte serial message is even.

#### 3.3.1 Interface Timing

A serial message sent earlier than  $\approx 987$  ms from the previous will not be recognized by the Controller. The following message will be acted on, whenever it arrives. The indication of such an early poll in the telemetry will be a zero filled minor frame, in between two consecutively numbered frames. In the event of APEX not receiving a response within 300ms of issuing a Data Request command, it is required to place a zero filled 256 byte data frame in the corresponding location in telemetry for that of a valid response.

A serial message sent later than  $\approx 1010.5$  ms from the previous message will enable the *time-out* bit (byte 165, bit 2) in the Controller Status telemetry. If biasing is underway when this occurs, the high voltage will be turned OFF. The following message will be acted on whenever it arrives; however, if it is correctly on the original 1-sec timeline, it will be regarded as being early.

The time interval between the transmission of the two serial bytes in a command from APEX is not to exceed 520 ms (one byte period at 19.2 kbits per sec).

### 3.4 Payload Commanding

The *NO-OP* (0000h) command is the only autonomously initiated PASP Plus command sent to the Controller. It is sent by APEX *in lieu* of a ground-initiated command, when there is none pending. There are four types of ground-initiated commands, and they are identified as follows: (1) Instrument Power Commands, which power ON and OFF the instruments in the PASP Plus complement; (2) TPM Specific Commands, to set various input detection thresholds for the instrument; (3) Array Biasing Commands, which configure and execute a bias sequence on any particular array; and (4) Array I-V Commands, which initiate additional I-V sequences on selected arrays.

### 3.5 Instrument Power Commands

There are specific Power Commands to turn ON and OFF the following: ESA, TPM, LP, QCM, QCM heater, and Emitter. These commands range in value from (1001h) to (110Fh), and are defined below in Table 3. Each is executed immediately on receipt by the Controller, with the exception that the TPM and Emitter will not power ON immediately when array biasing is in progress. They will do so at the end of the major frame in which the command is received. Both units will power OFF immediately, however.

Power Commands [Range = 1001h-110Fh]

| FUNCTION           | HEX VALUE |
|--------------------|-----------|
| ESA OFF            | 11 00     |
| ESA ON             | 10 01     |
| TPM OFF            | 10 02     |
| TPM ON             | 11 03     |
| Langmuir Probe OFF | 10 04     |
| Langmuir Probe ON  | 11 05     |
| DP QCM Heater OFF  | 11 06     |
| DP QCM Heater ON   | 10 07     |
| PS QCM Heater OFF  | 10 08     |
| PS QCM Heater ON   | 11 09     |
| Emitter OFF        | 11 0A     |
| Emitter ON         | 1X XB*    |
| DP QCM power OFF   | 11 0C     |
| DP QCM power ON    | 10 0D     |
| PS QCM power OFF   | 10 0E     |
| PS QCM power ON    | 11 0F     |

Table 3: Instrument Power Commands

\*The 'Emitter on' command is decoded as follows:

| Command Byte   |                |                |                |                |                |                |                | Data Byte      |                |                |                |                |                |                |                |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| D <sub>7</sub> | D <sub>6</sub> | D <sub>5</sub> | D <sub>4</sub> | D <sub>3</sub> | D <sub>2</sub> | D <sub>1</sub> | D <sub>0</sub> | D <sub>7</sub> | D <sub>6</sub> | D <sub>5</sub> | D <sub>4</sub> | D <sub>3</sub> | D <sub>2</sub> | D <sub>1</sub> | D <sub>0</sub> |
| 0              | 0              | 0              | 1              | 0              | 0              | 0              | Par            | T3             | T2             | T1             | T0             | 1              | 0              | 1              | 1              |

Par: Parity bit, such that total number of 1's in both bytes is even.

T3-T0: Duration that power should be applied to Emitter, as shown below.

| T3-T0 | Emitter power | T3-T0 | Emitter power | T3-T0 | Emitter power | T3-T0 | Emitter power |
|-------|---------------|-------|---------------|-------|---------------|-------|---------------|
| 0     | always on     | 4     | 30 min        | 8     | 90 min        | 12    | 220 min       |
| 1     | 1 min         | 5     | 40 min        | 9     | 110 min       | 13    | 260 min       |
| 2     | 10 min        | 6     | 60 min        | 10    | 150 min       | 14    | 330 min       |
| 3     | 20 min        | 7     | 75 min        | 11    | 180 min       | 15    | 370 min       |

### 3.6 TPM Specific Commands

These commands range in value from (2100h) to (2E00h) and are defined below in Table 4. Each is executed immediately on receipt by the Controller. The commands serve to vary the input threshold of the four Electric Field ( $\vec{E}$ ) sensors (Channels 0, 1, 3 & 4) and the Current Probe (Channel 5). There are four threshold levels (0-3), and the threshold rolls over when incremented at level 3.

*TPM Commands [Range = 2100h-2E00h]*

| FUNCTION                      | HEX VALUE |
|-------------------------------|-----------|
| Default thresholds            | 21 00     |
| Increment Channel 0 threshold | 22 00     |
| Increment Channel 1 threshold | 24 00     |
| Increment Channel 2 threshold | 27 00     |
| Increment Channel 3 threshold | 28 00     |
| Increment Channel 4 threshold | 2B 00     |
| Increment Channel 5 threshold | 2D 00     |
| Default thresholds            | 2E 00     |

Table 4: TPM Specific Commands

**Note** Input Channel 2 is unused.

### 3.7 Array Biasing Commands

There are three types of biasing-related commands. They are: (1) Bias Mode commands, which define the bias levels and other parameters; (2) Bias Select commands, which select the arrays to be biased; and (3) the Bias Upload command, which allows new bias levels to be uploaded for selection with the Bias Mode command. Details on each of these Bias Commands follow.

#### 3.7.1 Bias Mode Commands

The Bias Mode commands define the following four features: (1) positive and/or negative sequence of bias voltages to apply to an array; (2) whether to bias with or without a load; (3) type of load to use; and (4) duration of bias. The commands range in value from (3000h) to (3FFFh), and are defined below in Table 5.

*Bias Mode [Range = 3000h - 3FFFh]*

| Command Byte   |                |                |                |                |                |                |                | Data Byte      |                |                |                |                |                |                |                |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| D <sub>7</sub> | D <sub>6</sub> | D <sub>5</sub> | D <sub>4</sub> | D <sub>3</sub> | D <sub>2</sub> | D <sub>1</sub> | D <sub>0</sub> | D <sub>7</sub> | D <sub>6</sub> | D <sub>5</sub> | D <sub>4</sub> | D <sub>3</sub> | D <sub>2</sub> | D <sub>1</sub> | D <sub>0</sub> |
| 0              | 0              | 1              | 1              | < +Sequence >  |                |                | Par            | 0              | 0              | < -Sequence >  |                |                | L/NL           | S/R            | C/O            |

+Sequence: Positive bias sequence, i.e. {0 0 0} = sequence 0, {1 1 1} = sequence 7.

- Sequence: Negative bias sequence (as above).

Par: Parity bit, such that total number of 1s in both bytes is even.

L/NL: 1 = use load, 0 = don't use load

S/R: 1 = short circuit, 0 = optimum load resistor [irrelevant if L/NL = 0]

C/O: 1 = continuous biasing, 0 = one-time biasing

Table 5: Bias Mode Commands

In order to bias an array, a Bias Mode command must first be issued. It should then be followed immediately by a Bias Select command. Any other intervening command will invalidate the information transmitted by the prior Bias Mode command, and it will have to be re-sent in the correct sequence for array biasing to take place.

### 3.7.2 Bias Select Commands

The Bias Select commands defines which array is to be biased. The commands range in value from (4000h) to (47FFh) and are defined below in Table 6. Bias Select Commands received at the Controller that are not preceded by a Bias Mode command will be ignored. When the proper biasing command sequence is observed, however, biasing will commence immediately after receipt of a valid Bias Select command.

**Notes** There are some exceptions to this set of events:

(a) If a set of Bias Mode and Bias Select commands are received while a Continuous I-V command is being executed, the Controller will wait until the Continuous I-V is complete before biasing will commence.

(b) A Bias Mode sequence-0 command, sent to terminate an on-going bias sequence, will not be implemented immediately. It is executed at the end of the bias step on which it was received.

(c) In fact, if during an on-going bias sequence any Bias Mode command is received *without* an accompanying Bias Select command, biasing will terminate at the end of the bias step on which it was received. If a Bias Select command is then received, biasing will commence based on the information contained in both the Bias Mode and Bias Select commands.

(d) If a set of Bias Mode and Bias Select commands are received during an on-going bias sequence, the new bias sequence will commence at the end of the bias step on which it was received. On the basis of the previous Note (c), however, if the Bias Mode command is received before the end of the current step and the Bias Select command is received after, then biasing will cease for the period between receipt of the two commands.

**Bias Select [Range = 4000h - 47FFh]**

| Command Byte   |                |                |                |                |                |                |                | Data Byte      |                |                |                |                |                |                |                |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| D <sub>7</sub> | D <sub>6</sub> | D <sub>5</sub> | D <sub>4</sub> | D <sub>3</sub> | D <sub>2</sub> | D <sub>1</sub> | D <sub>0</sub> | D <sub>7</sub> | D <sub>6</sub> | D <sub>5</sub> | D <sub>4</sub> | D <sub>3</sub> | D <sub>2</sub> | D <sub>1</sub> | D <sub>0</sub> |
| 0              | 1              | 0              | 0              | 0              | A <sub>9</sub> | A <sub>8</sub> | Par            | A <sub>7</sub> | A <sub>6</sub> | A <sub>5</sub> | A <sub>4</sub> | A <sub>3</sub> | A <sub>2</sub> | A <sub>1</sub> | A <sub>0</sub> |

Par: Parity bit, such that total number of 1s in both bytes is even.

A<sub>9</sub>: Array 15; 1=Bias, 0=no bias.

A<sub>8</sub>: Array 14 (as above)

A<sub>7</sub>: Array 11 (as above)

A<sub>6</sub>: Array 8 (as above)

A<sub>5</sub>: Array 6 (as above)

A<sub>4</sub>: Array 5 (as above)

A<sub>3</sub>: Array 4 (as above)

A<sub>2</sub>: Array 3 (as above)

A<sub>1</sub>: Array 2 (as above)

A<sub>0</sub>: Array 1 (as above)

Table 6: Bias Select Commands

### 3.7.3 Bias Upload Commands

Biassing will usually occur at pre-defined voltage levels, as choosen by sequence number in the Bias Mode Command. The Bias Upload commands allow the possibility of uploading new voltage levels, for execution on the selection of bias sequence #7. Necessarily then, a Bias Upload command must precede Bias Mode and Bias Select commands, in order to be executed on the choosen array.

Table 7: Bias Upload Commands

*Bias Upload [Range = 8000h - FFFFh]*

| Command Byte   |                |                |                  |                |                |                |                | Data Byte      |                |                |                |                |                |                |                |
|----------------|----------------|----------------|------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| D <sub>7</sub> | D <sub>6</sub> | D <sub>5</sub> | D <sub>4</sub>   | D <sub>3</sub> | D <sub>2</sub> | D <sub>1</sub> | D <sub>0</sub> | D <sub>7</sub> | D <sub>6</sub> | D <sub>5</sub> | D <sub>4</sub> | D <sub>3</sub> | D <sub>2</sub> | D <sub>1</sub> | D <sub>0</sub> |
| 1              | < Step >       |                | < Array Number > |                |                |                | Par            | Pol            | < Bias Value > |                |                |                |                |                |                |

Step: Which bias step to upload; {0 0} = step 0, {0 1} = step 1, etc.

Array Number: Array for which bias is uploaded; {0 0 0 0} = array 0, {0 1 0 0} = array 4, etc.

Par: Parity bit, such that total number of 1s in both bytes is even

Pol: Polarity of sequence to upload; 1 = negative, 0 = positive

Bias Value: Bias value to upload, 0 - 127. Resolution is 3.92 volts/bit

Any voltage value between 0 - 498 Volts (with 4 V resolution) can be uploaded to each of the four steps in sequence #7. They will remain unchanged until new numbers are uploaded. These step values cannot be read-out and verified directly. However, the command echo can be monitored to observe that the proper command was sent. Also, when biassing is under-way on an array, both the array number, sequence number and step voltage value are telemetered and displayed on the GSE.

The Bias Upload commands range in value from (8000h) to (FFFFh) and are defined above in Table 7. They are executed immediately, except when sent during an on-going bias sequence. In this event, the command is executed at the end of the bias step in which it was received.

### 3.8 Array I-V Commands

Normal sampling of the Current vs. Voltage (I-V) characteristic of the arrays on PASP Plus is carried out routinely in one of two ways: (1) as a background task, in a manner which samples each module once before repeating the process; or (2) an I-V is taken on an array to be biased just prior to biassing commences on the module.

There is a set of commands, however, which permit I-V's to be sampled in a non-routine fashion. They are executed immediately, except when sent during an on-going bias sequence. In this event, the command is executed at the end of the bias step in which it was received. The commands range in value from (5000h) to (5FFFh) and are defined below in Table 8.



**Table 8: Array I-V Commands**

**Array I-V Commands [Range = 5000h - 5FFFh]**

| FUNCTION                            | HEX VALUE |
|-------------------------------------|-----------|
| Request update of all I/V curves    | 59 00     |
| Select continuous I/V for one array | 5X XX*    |

\*Format for 'Select continuous I/V' command is as follows:

| Command Byte   |                |                |                |                |                |                |                | Data Byte      |                |                |                |                |                |                |                |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| D <sub>7</sub> | D <sub>6</sub> | D <sub>5</sub> | D <sub>4</sub> | D <sub>3</sub> | D <sub>2</sub> | D <sub>1</sub> | D <sub>0</sub> | D <sub>7</sub> | D <sub>6</sub> | D <sub>5</sub> | D <sub>4</sub> | D <sub>3</sub> | D <sub>2</sub> | D <sub>1</sub> | D <sub>0</sub> |
| 0              | 1              | 0              | 1              | 1              | 0              | 1              | Par            | A <sub>3</sub> | A <sub>2</sub> | A <sub>1</sub> | A <sub>0</sub> | T <sub>3</sub> | T <sub>2</sub> | T <sub>1</sub> | T <sub>0</sub> |

Par: Parity bit, such that total number of 1's in both bytes is even

A<sub>3</sub> - A<sub>0</sub>: Array # for continuous I/V curves

T<sub>3</sub> - T<sub>0</sub>: Duration for I/Vs to be taken. [0 = cancel continuous I/V in progress, 1 - 15 = # of minutes]

## 4. ARRAY I-V MEASUREMENT AND BIASING

### 4.1 Array I-V Measurement

I-V data is of prime importance for the PASP Plus mission. A change in array performance will be reflected in the I-V curves for the array; consequently, much attention is paid to acquiring and telemetering this data.

Some 66 12-bit samples of current and voltage are taken for each I-V curve, with an active MOSFET load being used to facilitate the measurements. The two end points [I<sub>short circuit</sub> (I<sub>sc</sub>), V<sub>short circuit</sub> (V<sub>sc</sub>), and I<sub>open circuit</sub> (I<sub>oc</sub>), V<sub>open circuit</sub> (V<sub>oc</sub>)] plus the array temperature (or that of the closest neighbour for modules which do not have a RTD) are measured and telemetered separate (bytes 16-105 of telemetry minor frames 12-13) from the other 64 measurements of the I-V curve (bytes 16-111 of telemetry minor frames 14-29). The first of these samples (point 0) is near I<sub>sc</sub>, while sample point 63 is near V<sub>oc</sub>.

### 4.2 Default I-V Sampling

Immediately after being powered ON, the Controller will proceed to take I-V measurements of all 16 arrays. This will be accomplished within one minute. The Controller will then continually repeat the process, cycling through at a rate of 1 sample per telemetry major frame, and taking eight minutes to measure all 16 arrays. This is the *background* I-V mode of operation for the Controller. The order in which arrays are sampled and the corresponding telemetry major frame indicator, are shown below in Table 9. This sequence is applicable for all I-V measurements.

**Table 9: Telemetry Major Frame and Sampled Array**

| LS 4 bits of Major Frame | Array Sampled | LS 4 bits of Major Frame | Array Sampled |
|--------------------------|---------------|--------------------------|---------------|
| 0                        | 0             | 8                        | 4             |
| 1                        | 8             | 9                        | 12            |
| 2                        | 1             | 10                       | 5             |
| 3                        | 9             | 11                       | 13            |
| 4                        | 2             | 12                       | 6             |
| 5                        | 10            | 13                       | 14            |
| 6                        | 3             | 14                       | 7             |
| 7                        | 11            | 15                       | 15            |

### 4.3 Extra I-V Sampling

Just before applying voltage to a module in executing an array bias command, the I-V characteristic of the chosen array is measured. These data are telemetered as a separate block from that of the other I-V's, in what is identified as the Extra I-V block (bytes 16-111 of telemetry minor frames 10-11). These data are sampled for each of the four steps in a typical bias sequence. There is also an extra I-V slot for the array RTD,  $V_{OC}$ , and  $I_{SC}$  measurements.

**Note** Data is also telemetered in the Extra I-V block when the Continuous I-V command is being executed. The origin of this data block is explained in the following Section 5.3.

### 4.4 Sampling Commands

There are two commands that will allow the Controller to sample array I-V's in a different manner from the default *background* I-V mode of operation. They are: (1) the Update I-V command and (2) the Continuous I-V command. An explanation of how the commands work follows; the specific format for each is given in Section 3.8.

#### 4.4.1 Update I-V Command

This command instructs the Controller to immediately sample and obtain the I-V's for all 16 array modules. The Controller will then act as it would when powered ON and sample the arrays within  $\approx 1$  minute, then continue sampling at the slower *background* I-V rate of 1 I-V per telemetry major frame or all 16 array modules in 8 minutes.

**Note** If an Update I-V command is received by the Controller when array biasing is on-going, it will be executed when biasing is completed. However, the command will appear immediately in the Command Echo block in telemetry.

#### 4.4.2 Continuous I-V Command

This command tells the Controller to repeatedly take I-V's on a selected array, for a set period of time. Up to 15 minutes duration can be accommodated, and the samples will be acquired at a rate of 16 per minute or 8 in each telemetry major frame.

When this command is being executed, the I-V data is telemetered in the block normally used in the *background* I-V mode (bytes 16-111 of telemetry minor frames 14-29). The regular *background* I-V data is telemetered in the Extra I-V block (bytes 16-111 of telemetry minor frames 10-11) when it is sampled. This switch also occurs in the array RTD,  $V_{oc}$  and  $I_{sc}$  measurement block.

If this command is issued with a duration of 0 minutes, for an array whose I-V is already being continuously sampled, it will terminate I-V sampling at the end of the telemetry minor frame (i.e., within 1 second) in which it was received.

At the end of a Continuous I-V execution, the Controller will automatically execute an Update I-V command at the end of the following telemetry minor frame. Therefore, within  $\approx$  1 minute of the event, the telemetry data will be of the normal form and content.

- Notes**
- (a) If array biasing commands (Bias Mode and Bias Select) are received by the Controller when a Continuous I-V command is being executed, the Continuous I-V will be completed before biasing is initiated.
  - (b) If an Update I-V command is received by the Controller when a Continuous I-V command is being executed, it will appear immediately in the Command Echo block in telemetry, but effectively, it will be ignored. By default, an Update I-V command is executed by the Controller, at the end of a Continuous I-V execution.

#### 4.5 Array Temperature Measurements

Array Temperature indicators are provided by Resistive Temperature Device (RTD) sensors located in most, but not all, of the array modules. A temperature measurement is made immediately prior to an I-V measurement being taken on an array module. For modules which do not have a RTD the temperature of the closest neighbor that does is measured. Table 10 below identifies which RTD is sampled for each of the arrays.

The array temperature measurements, along with the two end points of the I-V curve ( $I_{sc}$ ,  $V_{sc}$ , and  $I_{oc}$ ,  $V_{oc}$ ), are telemetered in a single block (bytes 16-105 of telemetry minor frames 12-13).

#### 4.6 ARRAY BIASING

The ability to bias an array up to  $\pm 500$  V is one of the principal functions of the PASP Plus Controller. There are ten biasable arrays (#s: 1, 2, 3, 4, 5, 6, 8, 11, 14, 15). Any combination of these may be biased.

If more than one array is being biased, the highest numbered array is biased first at positive (+) voltage values (if selected), then at negative (-) voltage values (if selected). Biasing will then proceed on the next highest array in similar fashion, until all the arrays chosen have been biased.

**Table 10: Array Module and RTD Measured**

| Array Module # | RTD measured | Array Module # | RTD measured |
|----------------|--------------|----------------|--------------|
| 0              | #1           | 8              | #8           |
| 1              | #1           | 9              | #9           |
| 2              | #1           | 10             | #10          |
| 3              | #3           | 11             | #11          |
| 4              | #6           | 12             | #12          |
| 5              | #5           | 13             | #12          |
| 6              | #6           | 14             | #14          |
| 7              | #7           | 15             | #13          |

#### 4.7 Bias Sequence and Voltage

When the command to bias an array is issued, one of seven preset bias sequences, each consisting of four voltage steps, is selected. Seven of the bias sequences (#'s: 0 → 6) contain voltage step values that are programmed in ROM and cannot be changed. The voltage steps of Sequence #7 may be uploaded by ground command, via the Bias Upload command. This provision allows the possibility of customizing individual voltage steps for each biased array, if this becomes necessary.

Each of the four steps in Sequence #0 are pre-set to 0 Volts. Effectively no biasing occurs when this sequence is executed, and it provides the only means of terminating on-going biasing, if a command with this sequence is issued for the biased array. The specific voltages steps for the pre-programmed bias sequences are shown below in Table 11.

**Table 11: PASP Plus Bias Sequences and Voltages**

| SEQ # | STEP 0                                 | STEP 1 | STEP 2 | STEP 3 |
|-------|--|--------|--------|--------|
| 0     | No Bias (terminates on-going biasing)  |        |        |        |
| 1     | 75                                     | 100    | 125    | 150    |
| 2     | 200                                    | 240    | 280    | 320    |
| 3     | 360                                    | 400    | 450    | 500    |
| 4     | 200                                    | 300    | 400    | 500    |
| 5     | 160                                    | 180    | 200    | 220    |
| 6     | 240                                    | 260    | 280    | 300    |
| 7     | Upload with <i>Bias Upload</i> command |        |        |        |

The duration of each of the voltage steps in a bias sequence is 22 seconds. Biasing actually starts 6 seconds into a 30 second telemetry major frame, and ends 2 seconds before the end of the frame, in order to allow the Controller to carry-out some background housekeeping tasks. This timing sequence is also maintained during periods of *Continuous Bias* on any array.

#### **4.8 Array Biasing Commands**

There are three biasing related commands: (1) Bias Mode; (2) Bias Select; and (3) Bias Upload. The Bias Mode and Bias Select commands must be sent in immediate succession, in order to initiate biasing. See the preceeding Section 2.3 for full details on each of these commands.

#### **4.9 Biased Array I-V**

In addition to the normal array I-V data acquired in background mode for all 16 arrays, extra I-V measurements are made on the array that is under-going biasing, prior to the start of each bias step. This data is contained in the Extra I-V Curve blocks of telemetry minor frames #10 and #11.

#### **4.10 Arcing during Biasing**

The PASP Plus Controller is designed to operate in the presence of arcing during array biasing. The Instrument response and telemetry indicators are different for positive bias and negative bias arcs.

##### **4.10.1 Positive Bias Discharge**

Bias voltage is disabled if the electrometer detects a leakage current in excess of 20 mA, and restored at the end of the bias step on which the exceedance was detected. This could be as long as a bias step duration or 22 seconds, if the discharge is detected immediately on application of the bias voltage.

There is a Controller status bit in the telemetry (byte 165, bit 3) which, when it=1, indicates that the bias power supply was turned OFF during the previous major frame.

##### **4.10.2 Negative Bias Discharge**

Bias voltage is maintained for 22 seconds, regardless of arcing activity. A 1 M $\Omega$  current limiting resistor along with the array and cable capacitance, will limit the timing of a second discharge to  $\approx$  1 ms after a prior occurrence.

TPM diagnostics is the only means in telemetry to tell is arcing occurred during negative biasing.

## 5. TELEMETRY

The PASP Plus Controller receives a serial message from APEX once per second, consisting of a 2-byte PASP Plus command and a 2-byte APEX Data Request Command. The Controller responds to the Data Request by sending 256 bytes of data (one telemetry minor frame) to APEX within 300 ms after receipt of the command. In the event of APEX not receiving a response within this time, it is required to place a zero-filled 256-byte data frame in the corresponding location in telemetry for that of a valid response.

The PASP Plus telemetry is organized in a minor frame/major frame format. A minor frame contains 256 bytes of data and is one second in duration. A major frame is made-up of 30 minor frames and is thus 30 seconds in extent. Defining information on the PASP Plus Telemetry allocations is contained in the PASP Plus Telemetry Allocations section of the Amptek generated document *PASP-Plus COMMAND FORMATS & TELEMETRY ALLOCATIONS - Instruments, Housekeeping and Array Details for all 30 Minor Frames*.

### 5.1 General Minor Frame Allocations

The telemetered data is distributed over all 256 bytes; however, there are items in common to all 30 minor frames. This includes:

- Synch Word 'PASP' (in ASCII).
- Minor and Major Frame counters.
- Power Byte indicating ON/OFF status of controlled instruments.
- Command Echo indicating the last command received by the Controller.
- TPM instrument data.
- Subcommutated Housekeeping and Controller Status data.
- Emitter instrument data.
- Sun Sensor data.
- ESA instrument data.

Table 12 below shows the byte association for the foregoing.

Table 12: Minor Frame Allocations in Common

| <u>Bytes</u> | <u>Description</u>                             | <u>Bytes</u> | <u>Description</u> |
|--------------|--|--------------|--------------------|
| 0-3          | Sync word, 'PASP' (ASCII), '50 41 53 50' (hex) | 176-183      | ESA Energy 1       |
| 4            | Minor frame counter, 0-29                      | 184-191      | ESA Energy 2       |
| 5-7          | 24-bit major frame counter, byte 5=MSB         | 192-199      | ESA Energy 3       |
| 112          | Power byte                                     | 200-207      | ESA Energy 4       |
| 113          | spare  | 208-215      | ESA Energy 5       |
| 114-115      | Command echo, byte 114=MSB                     | 216-223      | ESA Energy 6       |
| 116-137      | TPM telemetry packet                           | 224-231      | ESA Energy 7       |
| 138-159      | TPM telemetry packet                           | 232-239      | ESA Energy 8       |
| 160-163      | Housekeeping                                   | 240-247      | ESA Energy 9       |
| 164-165      | Controller status                              | 248-255      | ESA Energy 10      |
| 166-171      | Emitter  |              |                    |
| 172-173      | Sun sensor sample 1                            |              |                    |
| 174-175      | Sun sensor sample 2                            |              |                    |

## 5.2 Specific Minor Frame Allocations

Additional instrument, array I-V measurement, and array bias status information are telemetered in specific minor frames. Accordingly, this is as follows:

### 5.2.1 Instrument Allocations

QCM Frequency (bytes 8-11 of minor frame 1)

Electrometer (bytes 8-15 of minor frames 7-29)

The Electrometer is sampled during minor frames 6-28 and telemetered one minor frame after it is sampled, in minor frames 7-29.

Langmuir Probe (bytes 16-87 of minor frames 1-8)

The Langmuir Probe is operated during minor frames 0-3.

### 5.2.2 I-V Measurement Allocations

Array I-V Curves (bytes 16-111 of minor frames 10-11, 14-29)

Each I-V curves consists of 64 pairs of 12-bit current and 12-bit voltage measurements. The curves are sampled such that point 0 is near  $I_{sc}$ , and point 63 is near  $V_{oc}$ . I-V curves for arrays 0-7 are sent in minor frames 14-29 of *even* major frames, and those for arrays 8-15 are sent in *odd* major frames.

Array RTDs (bytes 16-47 of minor frame 9)

All array RTDs are sampled periodically throughout a major frame such that the time between samples of a specific RTD is 30 seconds (one major frame).

Array RTD,  $V_{oc}$ ,  $I_{sc}$  measurements (bytes 16-105 of minor frames 12-13)

Minor frame 12 contains data from arrays 0-7 and the extra I-V while minor frame 13 contains data from arrays 8-15. Each RTD in this set of measurements is taken immediately prior to an I-V curve being taken on the respective array.

### 5.2.3 Array Bias Status Allocations

Bias Status (bytes 105-111 of minor frame 6)

Bytes 105-108: diagnostic

Byte 109: current HV setting (1.96V/count)

Byte 110: bit 7 1=positive, 0=negative

bit 6 n/a

bit 5 1=short, 0=no short

bit 4 1=no load, 0=optimum load (ignore if bit 5=1)

bits 3-0 array #

Byte 111: bit 7 1=bias active, 0=not active

bit 6 n/a

bit 5 1=positive, 0=negative (same as byte 110, bit 7)

bits 4-2 bias sequence #

bits 1-0 bias step #

**Notes** (a) If byte 111 has a value of zero, bias is not active; bytes 105-111 are then not applicable and should be ignored.

(b) Byte 109 is the current HV setting and is not a measured value. The high voltage measurement is located in housekeeping..

### 5.3 Housekeeping Allocations

The Controller housekeeping status information appears in all minor frames and is identified under the General Minor Frame Allocations on page 17. All of the PASP Plus analogs are telemetered in this block, and the information is considerably subcommutated in order to accommodate all of the data. The specifics of this telemetry block, as it appears in the defining document *PASP-Plus COMMAND FORMATS & TELEMETRY ALLOCATIONS—Instruments, Housekeeping and Array Details for all 30 Minor Frames*, is reproduced below.

Housekeeping (bytes 160-163)

Byte 160 = A/D offset (2.442 mV/count). This value (in counts) must be subtracted from all analogs before they are converted to engineering units! It should be subtracted directly from 12-bit analogs, but it should be divided by 16 before subtracting it from 8-bit analogs.

Byte 161 + MS 4 bits of byte 162 = subcommmed housekeeping analog (see table below for commutation scheme)

LS 4 bits of byte 162 + byte 163 = HV bias (122.1 mv/count)

The subcommmed analogs are identified by the minor frame counter, as listed below in Table 13.

Table 13: Subcommmed Analogs & Minor Frame

| MINOR FRAME | ANALOG                   | CONVERSION (C = COUNTS)        | NOMINAL VALUE | MINOR FRAME | ANALOG          | CONVERSION (C = COUNTS) |
|-------------|--------------------------|--------------------------------|---------------|-------------|-----------------|-------------------------|
| 0           | none                     | -                              | -             | 15          | DP QCM Temp     | see below <sup>3</sup>  |
| 1           | none                     | -                              | -             | 16          | PS QCM Temp     | see below <sup>3</sup>  |
| 2           | none                     | -                              | -             | 17          | CAL1 Temp       | see below <sup>3</sup>  |
| 3           | none                     | -                              | -             | 18          | CAL2 Temp       | see below <sup>3</sup>  |
| 4           | none                     | -                              | -             | 19          | CAL3 Temp       | see below <sup>3</sup>  |
| 5           | +28 V MON                | $V = C \cdot 0.01367$          | 28.000 V      | 20          | 0° RTD          | see below <sup>3</sup>  |
| 6           | +15 V MON                | $V = C \cdot 0.007287$         | 15.000 V      | 21          | none            | -                       |
| 7           | +5 V MON                 | $V = C \cdot 0.002442$         | 5.000 V       | 22          | Controller Temp | see below <sup>3</sup>  |
| 8           | -15 V MON                | $V = C \cdot 0.01222 - 40.03$  | -15.000 V     | 23          | ESA Temp        | see below <sup>4</sup>  |
| 9           | -5 V MON                 | $V = C \cdot 0.007319 - 19.97$ | -5.000 V      | 24          | Langmuir Temp   | see below <sup>5</sup>  |
| 10          | ESA LV MON               | $V = C \cdot 0.001233$         | 2.450 V       | 25          | Emitter Temp    | see below <sup>6</sup>  |
| 11          | ESA HV MON <sup>1</sup>  | $V = C \cdot 0.001233$         | -             | 26          | none            | -                       |
| 12          | Sun Sen. +10V MON        | $V = C \cdot 0.001233$         | 3.000 V       | 27          | none            | -                       |
| 13          | RTD REF                  | $V = C \cdot 0.002442$         | 0.334 V       | 28          | none            | -                       |
| 14          | 28 V Return <sup>2</sup> | $V = C \cdot 0.002442$         | -             | 29          | none            | -                       |

<sup>1</sup>The HV MON values for the 10 ESA energies are further subcommmed as a function of the lower 4 bits of the major frame counter, as shown in Table 14.

<sup>2</sup>This is a measurement of the voltage drop in the 28V return, which is a function of the cable resistance between the BCR and the Controller and of the current load of the Controller (which is a function of which PASP Plus subsystems are powered.)

<sup>3</sup>All RTDs are converted from counts to °C with the following formula:

$$T = 0.09784 C + 472.756 \text{ RTDREF} - 256.410 \quad (\text{RTDREF in Volts})$$

<sup>4</sup>ESA temperature is derived from the following formula:  $T = \frac{1}{.00335 + \frac{1}{3891} \ln\left(\frac{5}{.001233C} - 1\right)} - 273.90$



**Table 14: Subcommmed ESA Energy Levels & Minor Frame**

| MF MOD 16 | HVMON    | NOMINAL<br>VALUE | MF MOD 16 | HVMON     | NOMINAL<br>VALUE |
|-----------|----------|------------------|-----------|-----------|------------------|
| 0         | Energy 1 | 3.043 V          | 8         | Energy 9  | 1.412 V          |
| 1         | Energy 2 | 2.074 V          | 9         | Energy 10 | 0.956 V          |
| 2         | Energy 3 | 1.412 V          | 10        | none      | -                |
| 3         | Energy 4 | 0.962 V          | 11        | none      | -                |
| 4         | Energy 5 | 0.656 V          | 12        | none      | -                |
| 5         | Energy 6 | 4.460 V          | 13        | none      | -                |
| 6         | Energy 7 | 3.043 V          | 14        | none      | -                |
| 7         | Energy 8 | 2.073 V          | 15        | none      | -                |

<sup>5</sup>Langmuir probe temperature is derived from the following formula:

$$T = \frac{1}{0.0010295 + 0.0002391 \ln R + 1.568 \times 10^{-7} (\ln R)^3} - 273.15$$

where:

$$R = 10^4 \left( \frac{5}{0.001233C} - 1 \right)^{-1}$$

<sup>6</sup>Emitter temperature decoding is as follows:  $T = 74.247 - 0.0446 C + 1.421 \times 10^{-5} C^2 - 2.952 \times 10^{-9} C^3 + 1.641 \times 10^{-13} C^4$

#### 5.4 UPDATE I-V Command - Execution & Telemetry

In the execution of the UPDATE I-V command, the relationship between which array is sampled and the information that is placed in the telemetry is dependant on whether the command was received in an even or odd telemetry major frame. Array information must have been acquired before the information in the relevant telemetry block is meaningful. It is important also to note that it requires two major frames to telemeter information on all 16 array modules. The minor frame (mF) in which each array module is sampled and the data telemetered is shown in Table 14 for the Update I-V command issued in both even and odd major frames.

Table 15: UPDATE I-V Command Execution Sequences

| EVEN MAJOR FRAMES |               |                       | ODD MAJOR FRAMES |               |                       |
|-------------------|---------------|-----------------------|------------------|---------------|-----------------------|
| mF#               | SAMPLED I-V # | TELEMETERED I-V #     | mF#              | SAMPLED I-V # | TELEMETERED I-V #     |
| 0                 |               |                       | 0                |               |                       |
| 1                 |               |                       | 1                |               |                       |
| 2                 |               |                       | 2                |               |                       |
| 3                 |               |                       | 3                |               |                       |
| 4                 |               |                       | 4                |               |                       |
| 5                 | 0             |                       | 5                | 0             |                       |
| 6                 | 1             |                       | 6                | 1             |                       |
| 7                 | 2             |                       | 7                | 2             |                       |
| 8                 | 3             |                       | 8                | 3             |                       |
| 9                 | 4             |                       | 9                | 4             |                       |
| 10                | 5             | Extra I-V             | 10               | 5             | Extra I-V             |
| 11                | 6             | Extra I-V             | 11               | 6             | Extra I-V             |
| 12                | 7             | Param 0-7 & Extra I-V | 12               | 7             | Param 0-7 & Extra I-V |
| 13                | 8             | Param 8-15            | 13               | 8             | Param 8-15            |
| 14                | 9             | 0                     | 14               | 9             | 8                     |
| 15                | 10            | 0                     | 15               | 10            | 8                     |
| 16                | 11            | 1                     | 16               | 11            | 9                     |
| 17                | 12            | 1                     | 17               | 12            | 9                     |
| 18                | 13            | 2                     | 18               | 13            | 10                    |
| 19                | 14            | 2                     | 19               | 14            | 10                    |
| 20                | 15            | 3                     | 20               | 15            | 11                    |
| 21                |               | 3                     | 21               |               | 11                    |
| 22                |               | 4                     | 22               |               | 12                    |
| 23                |               | 4                     | 23               |               | 12                    |
| 24                |               | 5                     | 24               |               | 13                    |
| 25                |               | 5                     | 25               |               | 13                    |
| 26                |               | 6                     | 26               |               | 14                    |
| 27                |               | 6                     | 27               |               | 14                    |
| 28                |               | 7                     | 28               |               | 15                    |
| 29                |               | 7                     | 29               |               | 15                    |

## 6. TASK #2 - CHAWS EFFORTS

Task #2 is a study of wake-related issues in the Ionosphere. An experimental package, designated *CHAWS* for Charging Hazards and Wake Studies, has been assembled to fly as part of the Wake Shield Facility (WSF) Program, the first flight of which is scheduled to occur in February 1994 on the Space Shuttle. The CHAWS experiment contains several Retarding Potential Analyzers (RPAs) each with a simple planar anode. It became clear during the instrument calibration process, however, that the performance of the unit could be greatly enhanced if the anodes were of a different and more sophisticated design, with the inherent capability for incident particle discrimination in angular space.

A redesign of the CHAWS anode was then launched by Amptek, Inc., to incorporate a unique *wedge and strip* anode-array structure that satisfies the requirement for particle discrimination. If the potential of this array design were to be realized in terms of the quality and quantity of its data output, it is quite likely that it could serve as a replacement for the existing anode on future reflights of the the CHAWS instrument package on WSP.

### 6.1 Summary of Activities

The design of the *wedge and strip* anode array was completed and an initial proto-type fabricated early in this review period. After subjecting it to some performance and characteristics determining tests, however, it was deemed to be unsatisfactory in a number of areas. Among the most serious findings was that the strip impedance was some three orders of magnitude greater than that considered to be desirable; i.e., tens of kilo-ohms rather than the tens of ohms—which made the task of getting meaningful outputs from the device (in the frequency range required) almost impossible.

Discussions were held during meetings with PL/GPSG personnel about the characteristics and suitability of the design, as well as ways in which it might be improved. From these sessions, it became apparent that the tens of kilo-ohms strip impedance inherent to the design is a fatal flaw, which can only be mitigated by further re-design of the anode structure. This redesign was carried out and a new prototype array manufactured.

This redesigned *wedge and strip* anode proved, on inspection, to be improperly manufactured. The photo-lithographic equipment that the vendor utilized to lay down the wedge and strip patterns created unsatisfactorily broadened line-widths, which led, in corresponding fashion, to unacceptably poor anode performance. It was therefore necessary to locate another vendor who does have the proper equipment to do the job. A prospective source was subsequently found across the country in California with state-of-the-art laser writing equipment, which ought to be more than adequate for the task.

In the interim, the opportunity to further refine the design prior to this third fabrication attempt was taken advantage of by all concerned. After further discussions with PL/GPSG personnel on the desirability of including particular features in the design, some minor enhancements were made to the layout, prior to submitting it yet again for fabrication. It is anticipated that this unit should soon be available. It will then be thoroughly checked out, to ascertain its suitability for use as a replacement anode in the CHAWS instrument. A layout schematic of the latest *wedge and strip* anode design is shown in Figure 1.

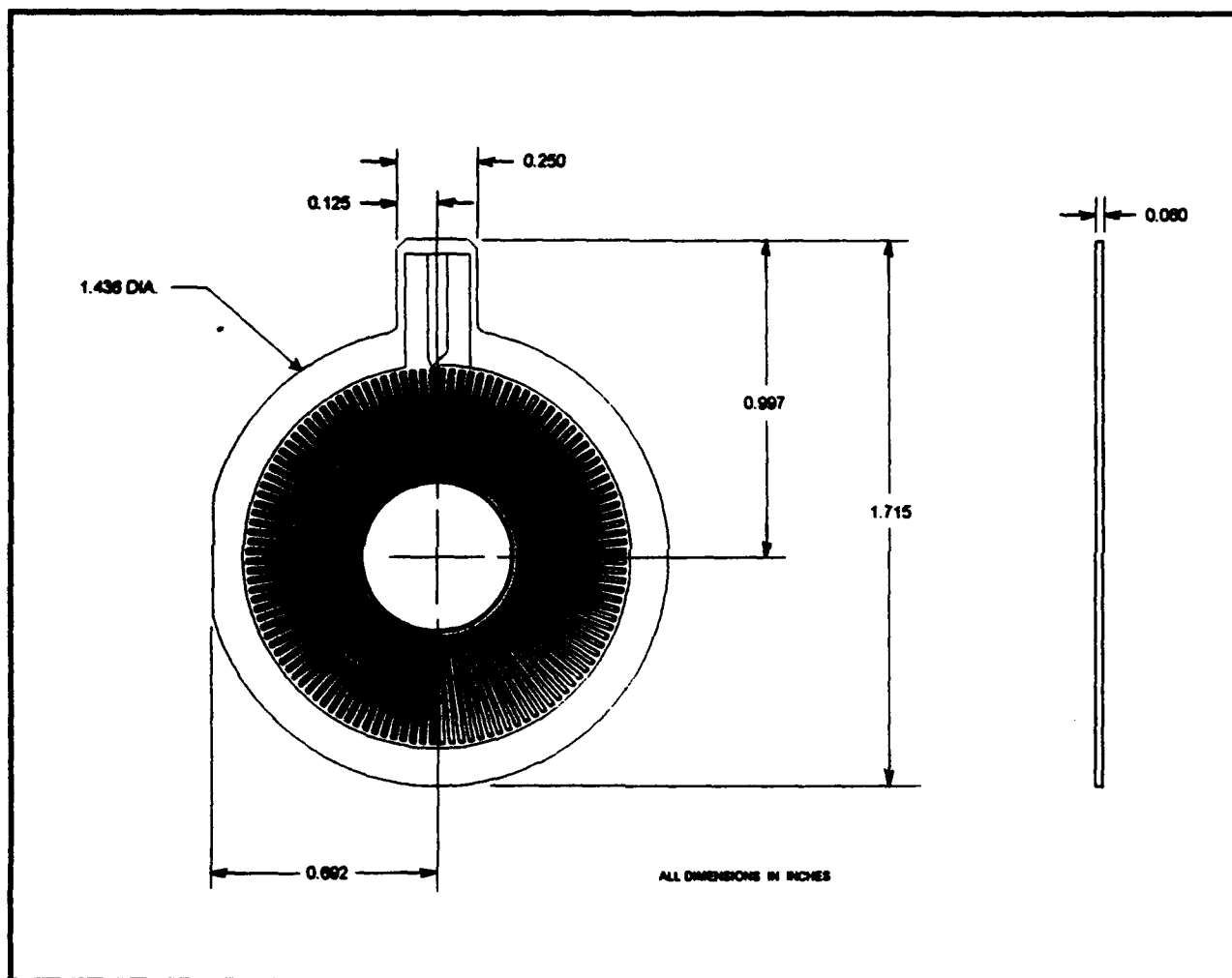


Figure 1: Layout Schematic of  
*wedge and strip Anode*

## 7. TASK #3 - SWIPE EFFORTS

The course of action and instrument implementation techniques that Amptek, Inc. has been developing for the Space Wave Interactions with Plasmas Experiment (SWIPE) are being applied to a sounding rocket mission designated as *Observation of Electric-field Distributions in the Ionospheric Plasma: a Unique Solution* or OEDIPUS-C. The "C" addition to the designation is in recognition of the fact that OEDIPUS-A was on launched January 30, 1989, and while an OEDIPUS-B was designed, it was not built. Design and payload enhancement to those employed in OEDIPUS-B are being implemented for the OEDIPUS-C launch. The objectives of the flight are very similar to those of SWIPE, which is a part of the Waves In Space Plasmas (WISP) experiment, to be conducted jointly by the Canadian Space Agency and NASA, with other U. S. Governmental Agency participation (including PL/GPSG). As can be seen in Figure 2, OEDIPUS-C is comprised of two payloads which are joined together by a 1 km tether, which is cut at both ends  $\approx 1\frac{1}{2}$  seconds after reaching apogee. The launch platform is to be a sounding rocket, launched from the Poker Flats Research Range in Alaska, over an active aurora. PL/GPSG will have identical instrumentation on both payloads. It is considered to be very important by the scientific investigators, that prototypes of the WISP experiments be flown and evaluated to obtain a better estimate of the likelihood of successful investigations on WISP itself. Further rationalization of the assignment of WISP experiments can then be made. Additional data to optimize specific parameters in scientific hardware (such as antenna types, lengths etc., or to sort out the dependence of certain physical phenomena such as sheet waves, on particular environmental parameters) could be obtained. WISP investigators could then re-specify and/or refine some experiment requirements for the mission.

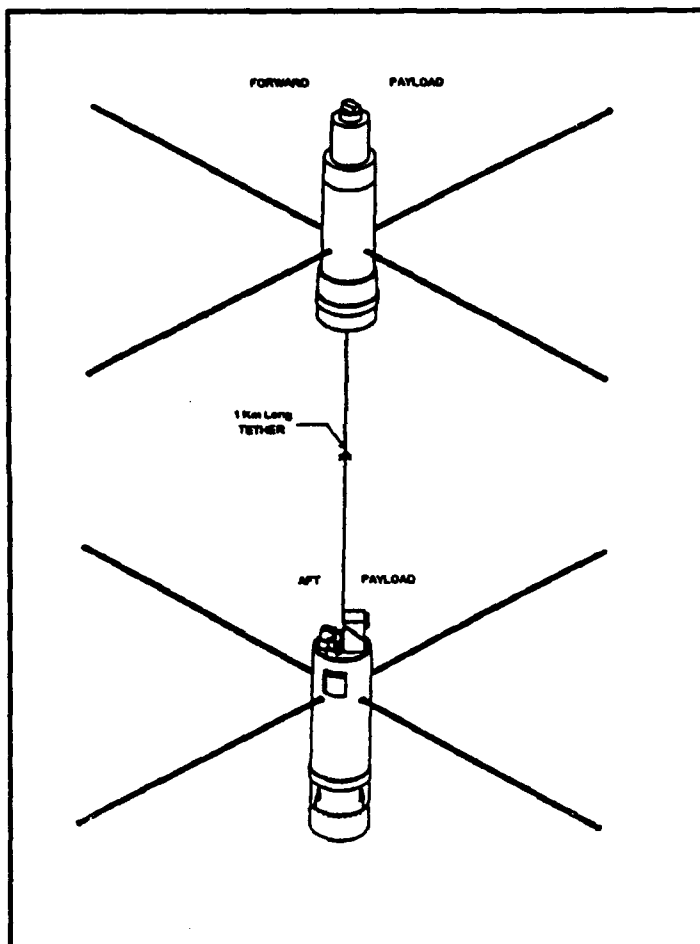


Figure 2: OEDIPUS-C Flight Configuration

### 7.1 Summary of Activities

The OEDIPUS-C program was first reviewed and an initial assessment made of the mission requirements, to provide PL/GPSG with some input on the appropriate design parameters to consider, for the ElectroStatic Analyzers (ESA's) they wish to fly on the mission. A consultant, expert in matters relating to the wave-particle correlation measurements to be made on the flight (and previously engaged for the SPREE mission on Shuttle flight STS-46), was retained to assist on this program. As it was then envisaged, two identical particle correlators were to be flown,

along with two identical ESAs (to measure electrons in the energy range of 10 eV to 20 keV) with one ESA and correlator pair on both the forward and aft payloads. Each ESA was to produce eight streams of electron arrival pulses, corresponding to eight zones in a 140 x 8 degree fan at two different rates of 1 and 8 counts per second. It was anticipated that the correlator modes would fall broadly into two categories: (1) 32-point autocorrelations in the frequency range 0-8 MHz summed at each energy level (32 energy levels from 10 eV to 20 keV). [This mode would be used to identify velocity resonant wave-particle interactions, and furthermore corresponds to the SPREE/Tether high frequency auto-correlation function outputs, a matter that allows for some ease in comparing the data from both flights during analysis.] (2) Each energy step was also to be divided into 32 equal time divisions of  $\approx 96$  ms duration. If the start of each energy step is synchronized to transmitter pulses, then the response of the plasma can be studied by summing up the time history as a function of energy steps. In the absence of a number for the anticipated data rates for these two modes (which was yet to be determined at this point), it was recognized that the trade-off between the two lay in the two alternatives of: (1) possible length of accumulation time (i.e., resolution) and (2) statistics (i.e., significance of input data).

An official OEDIPUS-C kick-off meeting was held at Hanscom AFB, and the main focus of the discussions centered around a conceptual design for the particle sensor, now designated the Energy Particle Instrument (EPI). Some attention was also given to formulating preliminary mission operation plans. Amptek, Inc. personnel participated in the discussions. Although the company will not be involved in the design or fabrication of the EPI, it will be responsible for the particle correlators into which the instrument outputs feed, as well as for the telemetry output that goes to the downlink transmitter. The OEDIPUS-C launch date was identified as Dec. 1, 1994 at the meeting, and a flight hardware completion date was set for June 30, 1994.

Efforts to determine the required hardware capability for EPI Electronics Module, which Amptek, Inc. is to provide, were carried out in a subsequent in-house meeting. The participants included the principal investigator Dr. David Hardy, the consulting scientist Dr. Paul Gough, and company personnel. The key determination coming out of the meeting was that an approximate number for telemetry rate was 250 kilobits per second for the mission. Additional hardware features, which were baselined then, include the following:

(1) High-Frequency Correlation

The 'buncher' technique will measure modulations up to 8 MHz in 16 energies and four directions at all frequencies of the transmitter; 157,286 bits will be generated per second. The hardware will be very similar in design to that flown on SPREE.

(2) Time Response

Histograms of flux variation over the electron-energy steps will provide 96  $\mu$ s resolution measurements of electron response to transmitter pulses; 65,536 bits will be generated per second. These units will be very similar in hardware to the LF correlators flown on SPREE.

(3) Fixed-Frequency energy response

A simple counting statistics approach will be used for the fixed-frequency periods to identify the energy-frequency interactions. The hardware here is again very similar to SPREE, this time to the 'beam' unit.

(4) Central Processing Unit (CPU)

A SPACE CPU will be used to access the above units, label data, and pass onto the main instrument processor for downlink.

Later in the review period, in an effort to make available a baselined version of the EPI electronics module housing to be flown on OEDIPUS-C, a preliminary drawing showing appearance, footprint, and volume was generated and presented to PL/GPSG for circulation. In other activities, consultations ensued among design personnel from Amptek and at Bristol Aerospace—the payload integrator—in an attempt to settle on a communications protocol between the OEDIPUS-C payload and the rest of the system. Bristol Aerospace and Amptek design personnel eventually settled on a communication protocol between the EPI's electronics module to be built by Amptek and the Telemetry Control Module on the rocket. It was decided that an asynchronous RS-422 link running at a "yet to be established" baud rate will be adequate for both parties.

Studies were also initiated on the counting statistics and statistical methods to be employed in the correlator themselves, in order to ensure that the sensor and the detection techniques employed will be sufficiently sensitive to make the desired measurements of the natural phenomena. This particular task made use of data accumulated by the SPREE instrument during Shuttle flight STS-46, since count rates and particle statistics will be similar—to a first approximation—for both missions. In an illustrative example of what can be accomplished in the forthcoming and recently much heralded *data superhighway* era, the studies were facilitated by a PC generating UNIX X-Windows displays of data fed to it via modem from the remotely located PL/GPSG SUN workstation on which the SPREE database resides (some three thousand miles away). Experience gained with the set-up will further enhance and expedite subsequent OEDIPUS-C post-flight data analysis and interpretation.

Some consideration was also given to the effects of a proposed change in the operational mode of the EPI instrument on the particle correlators within the DPU. The impact of an increase in the number of voltage steps from 32 to 33 and the reduction of each energy step from 3.1 ms to 3.03 ms were assessed. In both cases, it was determined that there would be little change to the contemplated design—only a small software change over that which was previously planned. It was also established that the use of an RS-422 link between the main CPU and the telemetry will have little effect unless the CPU has to access the SPACE section more often because of memory limitations. In any event, the dual port RAM interface between the CPU and SPACE correlators in the Electronics Module should provide a high level of immunity to timing conflicts between the two systems. Details on the specifics of the Correlator design, interfacing within the Electronics Module and completion schedules were left to be settled during meeting at Amptek, Inc. at a later date.

Amptek, Inc. personnel supported the second OEDIPUS-C Science Team Meeting, held at the Canadian Space Agency headquarters outside Montreal, Quebec. In addition to being a good familiarization opportunity for the people involved, several technical matters were brought to light and clarified (in most cases) or noted for future resolution. As an example of this, the frequency transmit scheme to be employed during the mission (and laid out in preliminary documentation) was somewhat confusing. Both PL/GPSG's and Amptek's understanding of the operational modes during the ascent phase of the mission was contrary to the design objective of the transmitter. The matter was clarified, and the new information incorporated into the relevant hardware design.

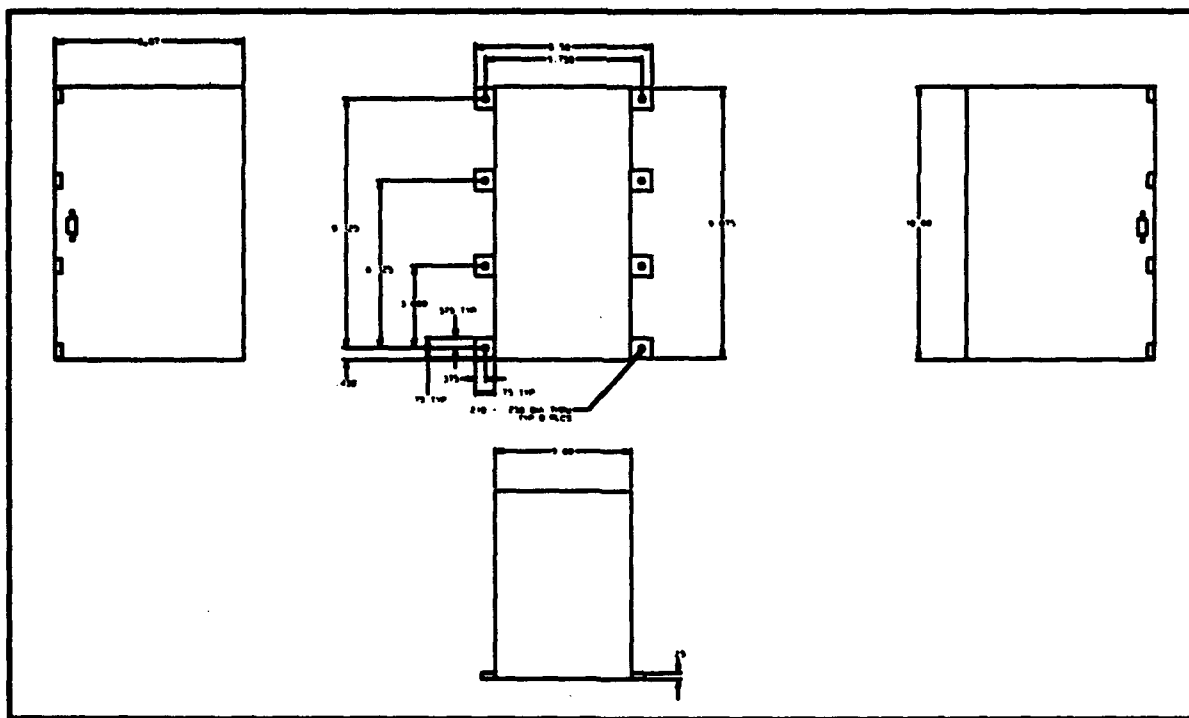
Shortly thereafter, work commenced on the design phase of the EPI sensor electronics module. In a meeting of project personnel at Amptek, Inc., discussions were held on the experiment's organization, systems, and division of responsibility for each task. The hardware and software design was blocked out, and all interfaces between on-board microprocessors identified.

In addition, all of the necessary software was sketched out in pseudo-code, in order to verify that the objectives could be met with the planned hardware. The conclusion of this exercise was affirmative, and detailed software writing commenced within the week.

## 7.2 Instrument Particulars

The EPI Electronics Module to be flown on OEDIPUS-C will be provided by Amptek, Inc. The unit's function is three-fold: (1) to process the output of the EPI sensor, which measures the number of electrons within the energy range of 10 eV to 20 keV in 8 discrete channels; (2) to carry-out various real-time, statistical, and time-history analysis, on the incident data; and (3) to packetize housekeeping, incident, and processed data for communication, via the rocket's Telemetry Command Module, to the downlink transmitter. Outline schematics are shown in Figure 3 below. The unit's specifications include:

|                     |                              |
|---------------------|------------------------------|
| Power Requirements: | 10.0 W NOM.                  |
| Input Voltage:      | $5 \pm 2\%$ VDC              |
| Outputs:            | TBD                          |
| Data Rate:          | $\approx 328$ kbits/sec MAX. |
| Dimensions:         | 10.0 in x 7.0 in x 5.0 in    |
| Weight              | 7.35 lb MAX.                 |



**Figure 3: OEDIPUS-C Electronics Module Outline Schematics**